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Productivity losses associated with premature mortality due to cancer in Russia: A population-wide study covering 2001–2030

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Abstract

Aims: Productivity losses related to premature cancer mortality have been assessed for most developed countries but results for Russia are limited to cross-sectional reports. The aim of this study was to quantify productivity costs due to cancer mortality in Russia between 2001 and 2015 and project this to 2030. *Methods*: Cancer mortality data (2001–2015) were acquired from the State Cancer Registry, whereas population data, labour force participation rates and annual earnings were retrieved from the Federal State Statistics Service. Cancer mortality was projected to 2030 and the human capital approach was applied to estimate productivity losses. *Results*: The total annual losses increased from US6.5b in 2001–2005 to US\$8.1b in 2011–2015, corresponding to 0.24% of the annual gross domestic product. The value is expected to remain high in 2030 (US\$7.5b, 0.14% of gross domestic product). Productivity losses per cancer death are predicted to grow faster in women (from US\$18,622 to US\$22,386) than in men (from US\$25,064 to US\$28,459). Total losses were found to be highest for breast cancer in women (US\$0.6b, 20% of overall losses in women) and lung cancer in men (US\$1.2b, 24%). The absolute predicted change of annual losses between 2011–2015 and 2026–2030 was greatest for cervix uteri (+US\$214m) in women and for lip, oral and pharyngeal cancers in men (+US\$182m). **Conclusions: In Russia, productivity losses due to premature cancer mortality are substantial. Given the expected importance especially for potentially preventable cancers, steps to implement effective evidence-based national cancer control policies are urgently required.**

Keywords: *Cancer, premature mortality, productivity losses, Russia*

Background

Cancer is the second leading cause of death in Russia [1]. While information on incidence reflects the causes of cancer, data for mortality capture combined information on relative success of primary and secondary prevention as well as on cancer management. Such data can be applied to illustrate societal burden, including economic impact. This latter can be separated into two components, namely direct healthcare expenses and indirect costs associated with lost contribution to the economy due to absence from work, known as lost productivity. Though often dismissed, lost productivity through premature cancer mortality of the working population may exceed treatment expenses and contribute substantially to the overall cost of cancer to societies [2].

Productivity losses related to premature cancer mortality have been assessed for most developed countries [3–10]. However, large-scale assessment of productivity losses has never been conducted in Russia and given recent efforts of the Ministry of Healthcare to implement cancer control strategies, such information is very necessary to guide design of national cancer control plans [11].

Aims

The aim of this study was to quantify this aspect of cancer burden by estimating years of life lost (YLL) and thereby calculate productivity losses due to premature cancer mortality in Russia in 2001–2015 and project this up to 2030.

Methods

General approach

We measured the YLL and the societal burden of cancer in Russia by assessing the impact of premature cancer mortality on productivity losses. Overall, YLL were calculated for six calendar periods (2001–2005, 2006–2010, …, and 2026–2030) by sex and 18 age groups for the following cancer sites, classified using ICD-10 (the International Statistical Classification of Diseases and Related Health Problems): lip, oral cavity and pharynx (C00–14), oesophagus (C15), stomach (C16), colorectum (C18–21), liver (C22), pancreas (C25), larynx (C32), trachea and lung (C33–34), bone (C40), skin (melanoma) (C43), soft tissues (C46.1,3,7–9,47,49), female breast (C50), cervix uteri (C53), corpus uteri (C54), ovaries (C56), prostate (C61), kidney (C64), bladder (C67), brain and central nervous system (C70–72, CNS), hematopoietic and lymphoid malignancies (C81–96) and all cancers combined including non-melanoma skin cancers (C00–96). The 'other' category included both cancer sites not mentioned earlier and unspecified cancer deaths. This was calculated as the difference between the number of all cancer deaths combined and the number of deaths from cancer-specific sites mentioned above. To estimate productivity losses due to cancer-related premature mortality in Russia in the period between 2001 and 2015 and projected until 2030 we applied an incidence-based method using the human capital approach (HCA).

Cancer mortality and population data

Age- and sex-specific cancer mortality data between 2001 and 2015 were acquired from the State Cancer Registry (SCR) based in the Herzen Research Institute of Oncology in Moscow [12]. A system of obligatory registration and lifetime follow-up of cancer patients was established in the USSR in 1953. Mortality data are collected by civil registration services and aggregated by the Federal State Statistics Service (FSSS). Population data, based on population censuses of 1989, 2002, 2010 and average population projections until 2031 were retrieved from the FSSS [13]. Age-standardized rates (ASRs) of cancer incidence and mortality per 100,000 person-years were calculated using the modified world standard population proposed by Segi [14]. In order to estimate trends over time log-transformed ASRs were calculated. To predict cancer mortality rates, we applied the Norpred prediction tool with a linear trend [15]. We derived age-specific YLL for each 5-year period calculated as a function of cancer deaths and life expectancy. Cause-deleted lifetables by period were generated based on data from the Human Mortality Database and forecasts with a functional demographic model [16, 17]. Methods and limitation of the analysis for data from the SCR were previously described [18].

All estimations were performed in open-source statistical software R (version 3.3.3, 2017-03-06)), using packages «nordpred» (accessed on 15 May 2016)[19] and «demography» (version 1.18) [20].

Economic data

The age- and sex-specific economic data were obtained from the FSSS: (a) labour-force participation rates (2001–2014); (b) averaged annual earnings (biennial, between 2002 and 2014); and (c) inflation rates (2001–2016). These data also included information on retirement and labour-force participation after retirement age (official retirement ages are 60 for men and 55 for women). Earnings were converted from Russian rubles to 2016 US dollars after adjustment for inflation based on yearly average currency exchange rates. We applied natural splines to interpolate employment rate integral and mean wages in 2001 and 2015, and also to project employment rates. For sensitivity analysis, wage growth was estimated based on two gross domestic product (GDP) scenarios: (a) GDP growth for 2016, 0.3%; 2018, 2.7%; 2022, 3.9%; 2024, 4.3%; 2027, 4.1%; 2030, 4%; and 2035, 3.8%, were used for base-case calculations, and (b) where GDP growth for 2016, 0.3%; 2018, 2.0%; 2022, 2.4%; 2024, 2.4%; 2027, 2.2%; 2030, 1.9%; and 2035, 1.7%, were used for sensitivity analysis.

Average age-specific wages weighted by age-specific labour force participation were then calculated. An annual discount rate of 2.5% was also applied for

base-case calculations [21]. For sensitivity analysis, we additionally applied discount rates of 0% and 5%. GDP based on purchasing power parity in 2011 international US dollars was acquired from the World Bank Database along with a deflator in order to transform the GPD to 2016 US dollars. In the base-case calculations, any earnings from work force participation were discontinued at the age of 70 as currently reported by FSSS. However, in the sensitivity analysis we also explored additional scenarios: where earnings were discontinued at an earlier age (65 and 55) and where earnings were not discontinued but projected to allow workforce participation until the end of life.

Estimation of lost productivity

The HCA assumes that economic output of an individual equates to wage rate, so that premature death, by cutting short the working life, produces economic losses to society equal to the lost earnings. To calculate productivity losses, we used age- and period-specific death and economic data. All results were expressed in 2016 US dollars. First (2001–2005), most recent (2011–2015) and last projected (2026–2030) periods for the base-case scenario were reported in Table I.

Ethical approval

This study utilized publicly available secondary aggregate data, and thus did not require, according to the current legislature, ethical approval.

Results

Trends in age-standardized mortality rates per 100,000 and YLL from cancer

Mortality for most cancer types was going down during the study period (Figure 1; Supplementary material Table S1). There was an upward trend between 2001 and 2015 for melanoma, pancreas, brain and CNS cancer mortality in both men and women, for lip, oral and pharynx, larynx and cervix uteri cancer mortality in women, and for prostate cancer mortality in men. Overall YLL increased for most cancer sites, except larynx in men, and stomach and bone in both men and women. The overall annual YLL due to premature cancer mortality in men increased from 11 million years in 2001–2005 to 12 million years in 2011–2015. It was predicted to further increase to 14 million years in 2026–2030.

Taking into account both relative and absolute changes in the overall YLL between 2001 and 2015, cervix uteri, pancreas and colorectal cancer showed the largest increases. Lip, oral and pharynx cancer showed the largest relative change, while cervix uteri cancer exhibited the largest absolute growth in women. Prostate cancer showed the highest absolute and relative increase in YLL in men, with major increases also in lip, oral and pharynx, colorectal and pancreas cancer in men in both relative and absolute terms (Supplementary material Figure S1).

Overall productivity losses and losses per one death

Annual productivity losses due to cancer mortality in Russia for the reported cancer types are presented in Table I. The annual overall productivity losses due to cancer mortality were reaching a peak of US$8.3b in 2006–2010 (US$3.2b in women and US$5.1b in men) (Figure 2).

Productivity losses per cancer death were higher in men (Table I). Yet, productivity losses per cancer death in women are predicted to grow faster than in men, from UD$18,622 in 2001–2005 to US$22,386 in 2026–2030. Productivity losses per cancer death were highest for bone, brain and CNS, cervix uteri, soft tissues cancer hematopoietic and lymphoid malignancies and melanoma of the skin (Supplementary material Figure S2).

In total, the estimated productivity losses decreased from 0.28% of GDP in 2001–2005 to 0.24% in 2011–2015 and are predicted to further decrease to 0.14% in 2026–2030. While this decline was seen for most cancer sites increases were found for lip, oral and pharyngeal, pancreatic, lung, cervix uteri in women; prostate in men; and oesophagus cancer in men and women.

Productivity losses by cancer type

Annual overall productivity losses were highest for breast cancer in women (US$0.6b or 20% of all losses in 2011–2015) and lung cancer in men ($1.2b or 24% in 2011–2015), which remain the highest-ranking cancers in the next two decades of the study period (Figure 2).

Relative change in productivity losses between 2011–2015 and 2026–2030 in women was highest for the larynx (174%), lip, oral and pharynx (152%), oesophagus (136%) and cervix uteri cancer (111%). During the same period, the absolute predicted change was highest for cervix uteri (+ US$214m) and lung cancer (+ US$61m) in women (Figure 3). In men, the relative change was highest for prostate cancer (111%), lip, oral and pharyngeal cancer (82%), oesophagus (64%), and liver cancer (69%), while the largest absolute increase was noted for lip,

Table I. Annual productivity losses due to cancer mortality, productivity losses per death (US$) and % of gross domestic product (GDP) adjusted for purchasing power parity by cancer, sex and period in Russia.

Cancer type (ICD-10)	Sex	Productivity losses 2016 US$m			Productivity losses per death, 2016 US$			% of GDP		
		2001–2005	2011–2015	2026–2030	2001–2005	2011–2015	2026–2030	2001–2005	2011–2015	2026–2030
Lip, oral cavity, pharynx (C00–14)	Women	27.0	50.5[a]	68.0	13,688	25,731	35,013	0.0011	0.0015	0.0013
	Men	222.5	322.8	405.3	26,251	38,871	49,033	0.0094	0.0094	0.0077
Oesophagus (C15)	Women	11.8	21.3	28.0	7734	13,672	18,155	0.0005	0.0006	0.0005
	Men	113.8	170.7	187.6	19,878	30,094	33,229	0.0048	0.005	0.0036
Stomach (C16)	Women	239.7	237.9	161.6	19,265	18,961	12,791	0.0102	0.0069	0.0031
	Men	518.5	522.8	362.4	31,149	30,640	21,094	0.022	0.0153	0.0069
Colorectal (C18–21)	Women	217.4	314.3	267.1	10,151	14,803	12,561	0.0092	0.0092	0.0051
	Men	257.8	402.7	361.5	13,971	22,124	19,972	0.0109	0.0117	0.0069
Liver (C22)	Women	53.2	70.1	73.9	12,798	17,047	18,029	0.0023	0.002	0.0014
	Men	113.3	165	180.4	20,669	30,440	33,737	0.0048	0.0048	0.0034
Pancreas (C25)	Women	71.9	122.9	115.9	8430	14,812	14,019	0.003	0.0036	0.0022
	Men	196.3	281.2	267.2	21,884	31,879	30,722	0.0083	0.0082	0.0051
Larynx (C32)	Women	4.8	7.9	13.1	15,885	26,697	44,887	0.0002	0.0002	0.0069
	Men	132.0	134.2	109.6	35,684	35,110	28,759	0.0056	0.0039	0.0021
Lung (C33, 34)	Women	115.8	174.4	177.0	12,273	18,589	18,938	0.0049	0.0051	0.0034
	Men	952.3	1206.5	968.0	23,259	29,094	23,378	0.0403	0.0352	0.0184
Bone (C40, 41)	Women	34.1	26.9	28.0	66,610	52,273	53,315	0.0014	0.0008	0.0005
	Men	70.8	61.6	58.9	107,636	93,561	87,423	0.003	0.0018	0.0011
Melanoma of skin (C43)	Women	47.8	62.9	60.2	25,092	33,306	31,854	0.002	0.0018	0.0011
	Men	61.9	83.3	81.9	37,198	51,050	50,186	0.0026	0.0024	0.0016
Soft tissues (C46.1,3,7–9,47,49)	Women	45.5	57.2	60.1	27,431	34,579	36,196	0.0019	0.0017	0.0011
	Men	70.9	91.5	99.0	45,857	59,415	64,514	0.003	0.0027	0.0019
Breast (C50)	Women	558.9	642.6	522.4	24,756	28,668	23,153	0.0237	0.0187	0.0099
Cervix uteri (C53)	Women	232.7	342.6	446.8	34,240	50,601	65,569	0.0099	0.01	0.0085
Corpus uteri (C54)	Women	99.0	145	137.9	14,426	21,358	20,272	0.0042	0.0042	0.0026
Ovary (C56)	Women	179.7	233.2	212.1	23,308	30,324	27,538	0.0076	0.0068	0.004

Table 1. (Continued)

Cancer type (ICD-10)	Sex	Productivity losses 2016 US$m			Productivity losses per death, 2016 US$			% of GDP		
		2001–2005	2011–2015	2026–2030	2001–2005	2011–2015	2026–2030	2001–2005	2011–2015	2026–2030
Prostate (C61)	Men	51.7	128.6	109.2	4332	12,151	10,589	0.0022	0.0038	0.0021
Kidney (C64)	Women	460	55.5	43.0	14,615	17,834	13,677	0.0019	0.0016	0.0008
	Men	135.4	173.2	132.6	25,632	33,180	25,398	0.0057	0.0051	0.0025
Bladder (C67)	Women	8.7	13.8	16.2	6150	9693	11,432	0.0004	0.0004	0.0003
	Men	66.6	88.8	64.3	13,183	17,197	12,404	0.0028	0.0026	0.0012
Brain, central nervous system (C70–72)	Women	140.0	165.7	186.3	37,720	45,747	52,049	0.0059	0.0048	0.0035
	Men	217.2	264.8	296.0	58,855	73,167	82,157	0.0092	0.0077	0.0056
Hematopoietic, lymphoid (C81–96)	Women	240.2	239	228.1	32,634	32,614	31,137	0.0102	0.007	0.0043
	Men	389.1	412.7	420.0	52,064	55,265	56,467	0.0165	0.012	0.008
Others[b]	Women	183.3	232.1	239.0	14,194	18,148	18,722	0.0078	0.0068	0.0045
	Men	341.3	426.3	408.7	28,867	36,447	35,031	0.0145	0.0124	0.0078
All cancer types combined (C00–96)	Women	2,547.8	3,204.4	3,053.4	18,622	23,492	22,386	0.1079	0.0935	0.0581
	Men	3,969.4	4,926.6	4,496.5	25,064	31,070	28,459	0.1681	0.1437	0.0855
Overall (sexes combined)	-	6,517.2	8,131.0	7,549.9	-	-	-	0.276	0.2372	0.1436

[a]Red cells represent increased losses compared with the previous period, green cells – reduced, grey – stable.
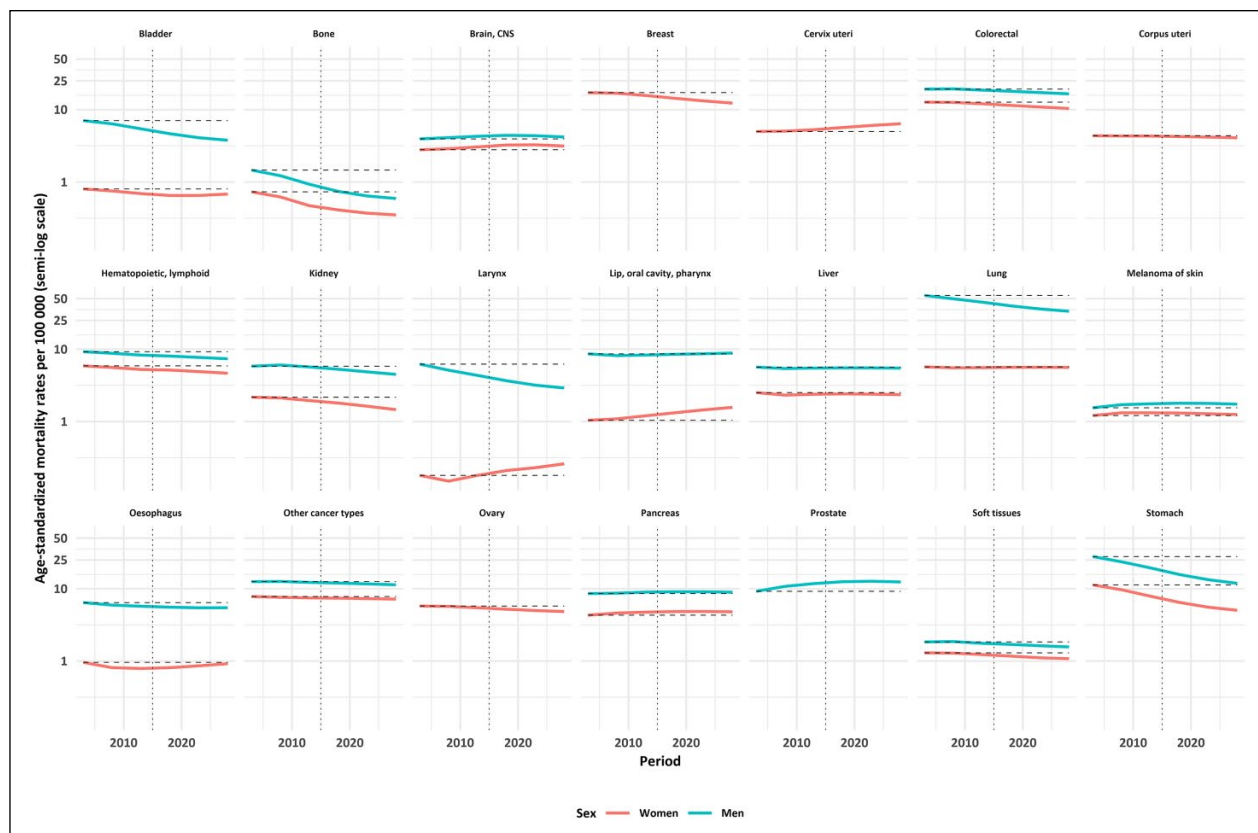[b]Other cancer types includes all other cancers not specified above.

Figure 1. Age-standardized mortality rates per 100,000 (presented on a semi-log scale) according to cancer types and sex between 2001 and 2030 in Russia (dash–dot line separates recent and future predicted rates).

oral and pharyngeal (+ US$182m) and colorectal cancer (+ US$103m) (Figure 3).

Sensitivity analyses

Changing the discount rate affected the overall amount of annual productivity losses but did not affect the relative distribution of losses by cancer types (Supplementary material Figures S3 and S4). Cutting the earnings at a certain age decreased the amount of productivity losses. In the scenario, where earlier age at earnings was discontinued, more productivity losses were assigned to cancer types affecting younger age groups (e.g. cervix uteri) and less productivity losses to those with deaths at older age groups (e.g. prostate) (Supplementary material Figures S5–S7). However, the major findings reported for the base-case scenario remained. The maximum overall annual productivity losses for 2011–2015 were reached without discontinuation of earnings with 0% discount and the base-case GDP growth scenario – US$4.03b in women and US$6.04b in men – while the lowest figures were obtained with discontinuation at the age 55 with a 5% discount and the second GDP growth scenario

– US$1.52b in women and US$2.11b in men (Supplementary material Figures S9–S10).

Discussion

To our knowledge, this is the first analysis of trends and prediction of cancer mortality related productivity costs in Russia. A large overall cost of cancer death in Russia was found amounting to US$8.1b or 0.24% of GDP in 2011–2015. It is expected to remain high in 2030 (US$7.5b or 0.14% of GDP). The result also provides a wide perspective of major contributors to these losses, the greatest cause being lung cancer (US$1.2b or 24% of the total loss) in men and breast cancer (US$0.6b or 20%) in women in 2011–2015. Quantitative assessment of the rising losses linked to cancers known to be related to human papilloma virus (HPV) infection, revealed a figure for cervical cancer in women of US$233m in 2001, which is expected to almost double to US$447m in 2030. This study provides an economic appraisal for the Russian government to set priorities in cancer control activities, including primary prevention (e.g. tobacco control or HPV control) and population-based cancer screening (cervical, breast and colorectal).
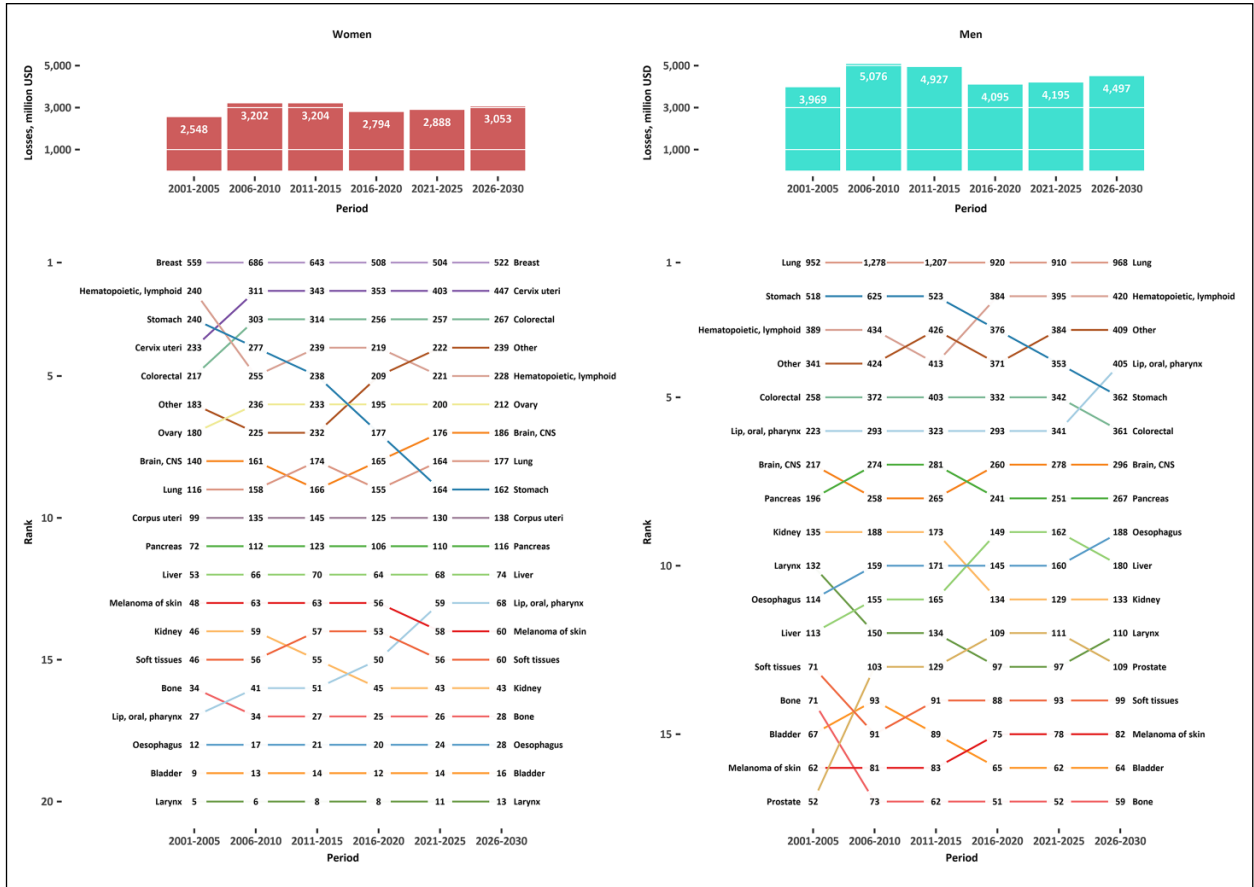
Figure 2. Overall observed and predicted average annual productivity losses due to premature cancer mortality in Russia in 2001–2030 and ranking according to cancer sites and sex.

Our findings can be compared with reports from other countries, which give similar relative estimates when costs are compared to GDP, taking into account differences in mortality and population size. In Europe, productivity losses due to cancer mortality in 2008 were 0.36% of total GDP ranging between 0.15 and 0.67% by country [22]. In the USA, productivity losses were higher: about 1.11% of GDP based on the 2000 estimates [3]. Cancer mortality related productivity costs in BRICS countries in 2008 were estimated as 0.21% GDP for Brazil, 0.25% for Russia, 0.34% GDP for China, 0.36% GDP for India and 0.49% for South Africa. Our results were consistent with these findings. [10].

We estimated an annual loss of US$8.1b due to premature deaths from cancer in Russia in 2011–2015. Extrapolating this estimate to total costs of cancer in Russia without high-quality data for direct medical costs related to cancers remains challenging. In a recent systematic review the proportion of cancer mortality related productivity losses was reported to be over 50% of the total cost [7]. However, in a large European study this proportion ranged from 24 to

54% for 27 countries [22, 23]. With some uncertainty, overall cancer costs in Russia can be estimated to be at least US$15b but probably more than US$20b per year based on extrapolation from our findings.

Productivity losses by cancer type

In general, we have observed a decline in the mortality from cancers in Russia with ASRs dropping between 2001 and 2015 from 94 to 87 per 100,000 in women (7%) and from 190 to 167 per 100,000 in men (12%), which reflected a decrease in the burden of cancer to the GDP from 0.27 to 0.24%. Some of this decrease can be related to the decline in smoking-related cancers in Russia as much of the productivity losses, particularly among men, are driven by smoking-related cancers such as lung cancer (24% of the total productivity loss in 2011–2015). The Russian Federation has been a Party to the WHO Framework Convention on Tobacco Control since 2008 and Federal Law on Health Protection from Exposure to Environmental Tobacco Smoke and the Consequences of Tobacco Consumption was adopted in 2013 – actions that
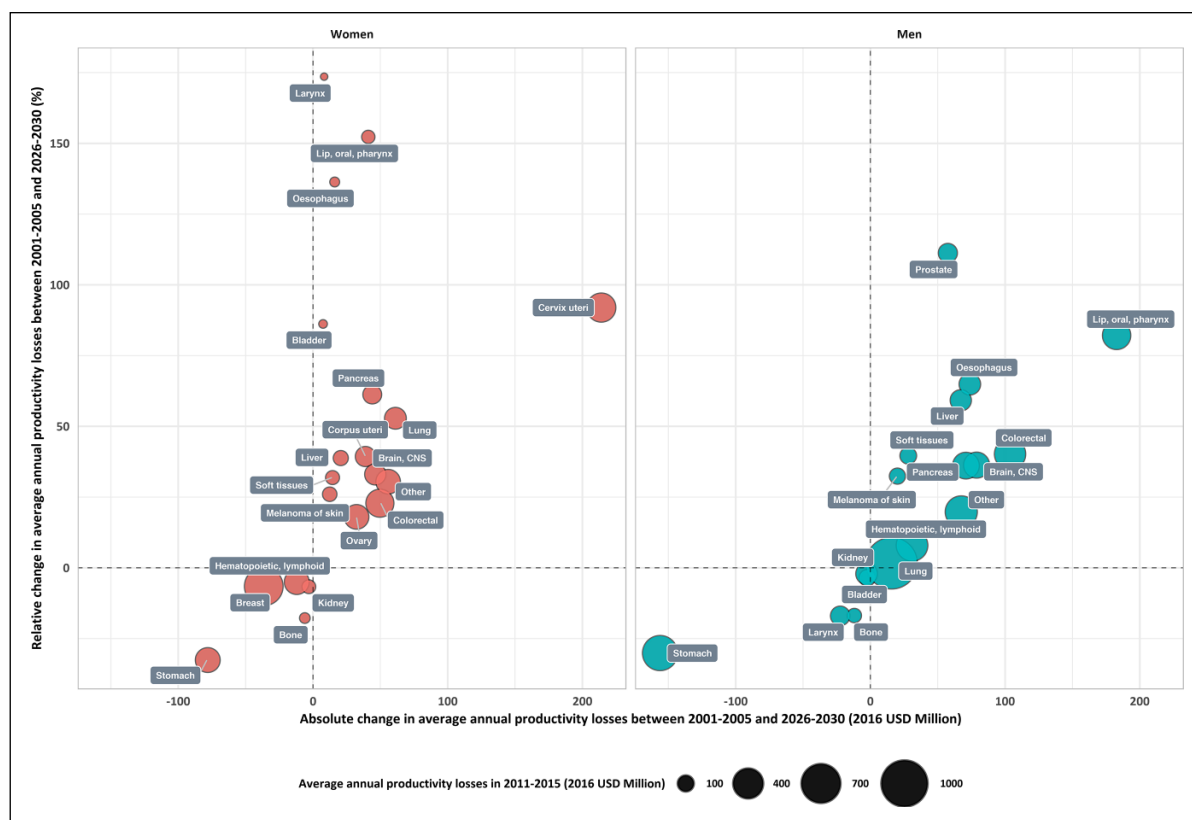
Figure 3. Change in in annual productivity losses due to premature cancer mortality in Russia between 2001–2005 and 2026–2030 according to cancer type and sex.

clearly will contribute to further mortality decline. Yet, the smoking prevalence remains high among men in Russia (daily smoking for 51% of men in 2015) [24]. Unlike many reports in other European countries, costs associated with women lung cancer deaths were moderate, ranking eighth of all costs in women probably related to a relatively low daily smoking prevalence (i.e. 15% in 2015) [24]. A slight increase in rates of lung cancer has been observed in women and continued increase in lung-cancer rates reported in other countries caution for a similar rise in Russia. Considering these factors, additional smoking cessation counselling might be implemented as part of screening programmes [25].

On the other hand, we saw a substantial increase in the contribution of HPV-related cancers (cervix uteri, oral and pharynx) to future productivity losses in Russia. At the moment, HPV vaccination is not available as a nationwide programme and cervical cancer screening remains opportunistic for a select proportion of the population [26]. Rising productivity losses from oral and pharynx cancers in both sexes adds additional motivation to put forward population-based HPV control activities at the national level.

We also saw a rapid rise in productivity losses from oesophagus, liver and pancreas cancer mortality, all

traditionally related to smoking and alcohol consumption, that can also be partly explained by the increasing obesity prevalence in Russia and other lifestyle risk factors [27]. In addition, growing incidence and substantial losses from colorectal cancer mortality as well as a large contribution of breast cancer to the economic cost underline the need to assess the major risk factors for these cancers and also the effectiveness of early detection and management in order to adapt existing national control policies.

A few limitations of the study should be noted. Quality of the data used in the analysis may affect the result, and as such the data input for this study needs to be considered when interpreting reported results. The 'other cancer types' category in our analysis consisted of two groups: the first including unspecified tumors (C76–C80) with around 4% out of the total reported deaths. The second group is other specific cancer types (around 3%), for which data were not available for the whole study period. The HCA is only one of several approaches to estimate societal burden of cancer. The friction cost approach (FCA) is an alternative. As such, losses based on the HCA calculations are considerably higher than calculated by FCA [28]. Yet, the HCA has become widely used and the methodology has

become a standard to estimate productivity losses for calculating indirect non-medical costs due to mortality [23, 29]. This analysis includes only paid productivity losses, so other indirect and direct losses, like unpaid work such as caring for children or sick relatives, and volunteering work, as well as other payments, are not included. Additionally, our method does not consider productivity losses that occur due to illness and disability, and hence loss of income, related to cancer. Estimating individual losses is an optimal approach but it is rarely feasible and renders such results incomparable to other studies due to differences in data collection and availability [30]. Furthermore, projected losses need to be carefully interpreted due to uncertainty in the economic, population and cancer predictions.

The primary strength of our study is that we provide comprehensive analysis of the trends and changes in productivity losses over time while most similar studies report cross-sectional findings. That allowed us to capture how the changing cancer burden is affecting economic losses in Russia. We used combined economic and epidemiological data available for the whole period of the study. In the absence of the reliable individual-level data, results of our and similar studies must be used to approximate the overall cancer costs in Russia, but future research would benefit from having more detailed data to estimate the economic burden of cancer in Russia.

Conclusions

Productivity losses due to premature cancer mortality in Russia are substantial and amount to US$8b per year. The losses are expected to drop from 0.28% of GDP in 2001 to 0.14% in 2030 mostly due to a decline in the mortality from cancers in Russia. While the losses are highest for breast cancer in women and lung cancer in men, the relative growth in productivity losses was highest for HPV-related cancer mortality.

Conflict of interest

None declared.

Supplemental material

Supplemental material for this article is available online.

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